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Intra-articular pressure based stress analysis of the distal tibia following insertion of a total ankle replacement

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Introduction

The ankle joint plays an important role in transferring the human body weight to the ground. Given the associated loading, Osteoarthritis (OA) is one of the most common disorders in the ankle joint. The most common treatment of ankle OA is total ankle arthroplasty (TAA). However it is not known whether TAA influences the stress levels of the bone structures and specially the distal tibia. Clinical studies previously related the occurrence of tibia cysts to focal stress concentrations.

In this research, we used the finite element analysis (FEA) to calculate the stresses within the ankle joint and to predict the value and position of maximum stresses in the tibia before and after TAA insertion. A unique feature is the use of actual measurements of in-vitro pressure distribution in the joint during gait as boundary conditions(3).

Methods

Computed topography (CT) scans of nine cadaveric feet, including the distal part of the tibia, were used to generate volume meshes pre and post TAA surgery. For the postoperative models, the geometry scans of three different sizes of HINTEGRA (New Deal, Lyon, France) TAA, obtained through 3D laser scanning, were used. Based on the gray values in the CT-scan cortical and trabecular parts of the bones were separated, using Mimics v17 (Materialise, Leuven, Belgium). Material assignment was based on the gray values for cortical and trabecular bone (Table 1). During the FE simulation, the maximum pressure magnitude that was measured during simulated gait(3) was applied on the bottom surface of the prosthetics component as well as on the inferior articular surface of the native ankle joint. The most proximal surface of the tibia was constrained. The analysis was performed using Abaqus v6.13 (Dassault Systèmes, Vélizy-Villacoublay, France) and maximal von Mises stresses in the distal part of the tibia were determined and averaged over all specimens.

Results

The estimated median peak stress was 1.36 MPa in the native joints and increased to 21.71 MPa in the TAA joints (Figure 1).

Conclusions

Insertion of a TAA significantly increases the stresses in the distal tibia. These high stresses need to be considered with caution as they can cause micro-fracture and degenerative bone remodeling in the tibia which might be related to the clinically observed cyst formation(4).

References

1.Cowin SC. The mechanical properties of cortical bone tissue: CRC Press, Boca Raton, FL; 1989.
2.Jensen NC, Hvid I, Krøner K. Strength pattern of cancellous bone at the ankle joint. Engineering in medicine. 1988;17(2):71-6.
3.Natsakis T, Burg J, Dereymaeker G, Sloten JV, Jonkers I. Extrinsic Muscle Forces Affect Ankle Loading Before and After Total Ankle Arthroplasty. Clinical Orthopaedics and Related Research. 2015:1-10.
4.Besse J-L, Brito N, Lienhart C. Clinical evaluation and radiographic assessment of bone lysis of the AES total ankle replacement. Foot & ankle international. 2009;30(10):964-75.

Figures and Tables

Table 1 – Material Properties(1, 2)

Material	E (MPa)	Poisson's Ratio
Trabecular Bone	500	0,3
Cortical Bone	19000	0,3
Wrought cobalt-Chromium-molybdenum ally	230000	0,3

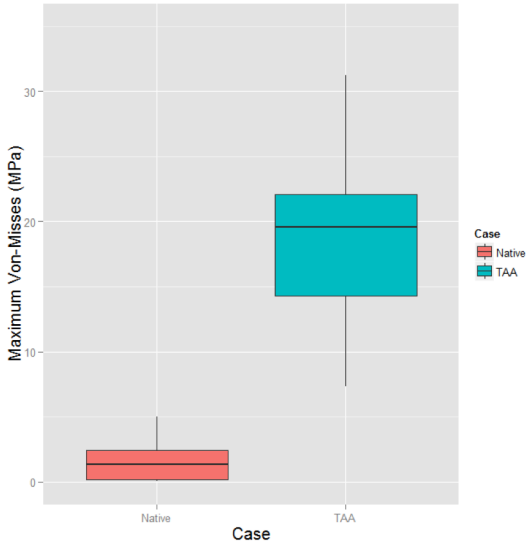

Figure 1- The median, lower and higher variation of von-Misses stresses in Native (Red) and TAA (Blue) joint.